CHAPTER 3

FILTERS FOR THE NUCLEAR INDUSTRY

3.1 INTRODUCTION

Filters are widely used in nuclear ventilation, air cleanup, and containment systems to remove particulate matter from air and gas streams. Air filters are defined as porous structures through which air is passed to separate out entrained particulate matter. The word "filter" is derived from the fabric called felt, pieces of which have been used for air and liquid filtration for hundreds of years. The porous structures of a filter may also be composed of granular material such as sand or fibers derived from cotton, minerals (glass, asbestos), metals, or a wide selection of plastic materials. For filtration purposes, the fibers may be woven or felted into a cloth or formed into a paper-like structure. Filters may also be constructed in the form of highly porous fibrous beds of considerable depth. Other types of air cleaning devices (e.g., adsorbers, liquid scrubbers, electrostatic precipitators) are sometimes referred to as "filters" because they are capable of removing particles from an air stream. For clarity, the strict definition of a filter (given above) will be used in this chapter.

3.1.1 AIR FILTER TYPES

Air filters of many types and materials of construction have been designed, manufactured, and applied to meet a wide variety of industrial and commercial requirements for clean air (e.g., the nuclear industry makes full use of all filter types). Commercially available filters are divided into three distinct categories based on how they operate to remove suspended particulate matter from the air passing through them. The largest category, often referred to as ventilation or heating, ventilation, and air conditioning (HVAC) filters, is composed of highly porous beds of resin-bonded glass or plastic fibers with diameters ranging from 1 to 40 μm. The fibers act as targets for collecting airborne dust. As their name indicates, HVAC filters are widely used for air cleaning in mechanical ventilation systems. They are almost all single-use, disposable items, and are used in all sectors of the nuclear industry, including as prefilters that reduce the amount of coarse dust reaching more efficient filters located downstream.

A second category also is comprised of single-use, disposable filters called high-efficiency particulate air (HEPA) filters. By definition,[1] a HEPA filter is a throwaway, extended-medium, dry-type filter with (1) a minimum particle removal efficiency of no less than 99.97 percent for 0.3-μm particles, (2) a maximum resistance, when clean, of 1.3 in.wg when operated at rated airflow capacity, and (3) a rigid casing that extends the full depth of the medium (**FIGURE 3.1**). A filter of identical construction and appearance, but having a filtering medium with a retention of 99.9995 percent for 0.1 μm particles, is referred to as an ultra-low penetration aerosol filter (ULPA). The filtering medium of HEPA filters is thinner and more compressed, and contains smaller diameter fibers than HVAC filters. HEPA filters are widely used throughout all phases of the nuclear industry.

A third category of commercial air filters is known as industrial cleanable cloth filters. As the designation indicates, these filters have built-in mechanisms for periodically cleaning the filtering surfaces of accumulated dust. Unlike the first two types, industrial cleanable cloth filters rely on building a thick layer of dust on the surface of the cloth to provide a high-efficiency filtering medium. This type of filter is used in the nuclear industry for ore processing and refining and for similar tasks involving high concentrations of coarse mineral dusts.

In addition, the nuclear industry uses special types of particulate filters for chemical and combustion operations. These include deep beds of sand in graded granular sizes, deep beds of glass fibers, and stainless steel membranes formed from compressed and sintered granules or fibers.

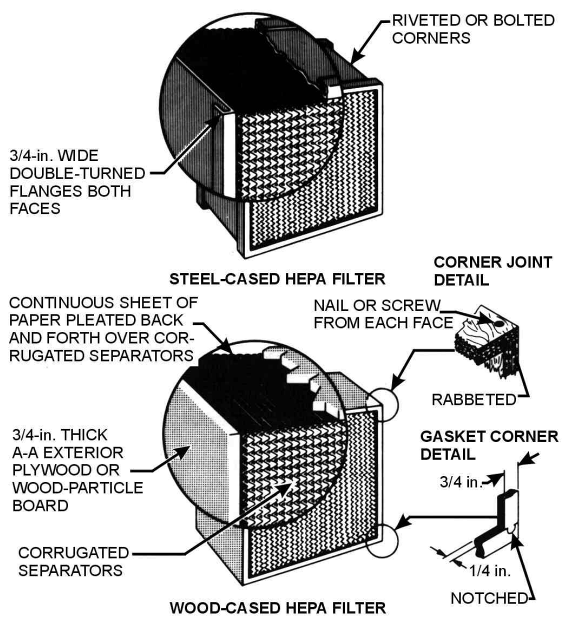

Figure 3.1 – Filter casing

Stainless steel membrane filters operate like industrial cleanable cloth filters in that they depend on a dust layer for high-efficiency particle removal and must be cleaned periodically, usually by reverse compressed air jets.

3.2 Filtration

The porosity of air filters has been noted. High porosity is associated with low resistance to airflow (e.g., low-resistance HVAC filters contain approximately 97 percent voids). In a uniformly dispersed filter medium, the individual fibers are relatively far apart—so far apart that the gaps between them are larger than the particles removed from the air. This means that sieving (particle removal via openings that are smaller than the particle dimensions) is not an important filtration mechanism. In fact, a sieve would make a poor air filter, even one containing submicrometer openings, because each collected particle closes up a sieve opening so that very soon no air can pass through. In contrast, real filters collect particles from air and gas streams in a number of well-defined ways that are associated with the dynamic properties of airborne particles as they respond to the physical forces present as an aerosol passes through a porous medium composed of small granules, fibers, or other shapes.

3.2.1 Particle Collection by Filters

FIGURE 3.2 shows the streamlines around a spherical granule or a single filter fiber lying normal to the flow direction. A particle entering the flow field surrounding the fibers must follow the curved path of the streamlines before it can pass around the obstacle. When particles possess sufficient inertia, they resist following the curvature of the air stream and come in contact with the fiber because of their higher momentum relative to that of the conveying gas molecules. The effect becomes greater as both aerodynamic equivalent diameter and the velocity of the air approaching the fiber increase.

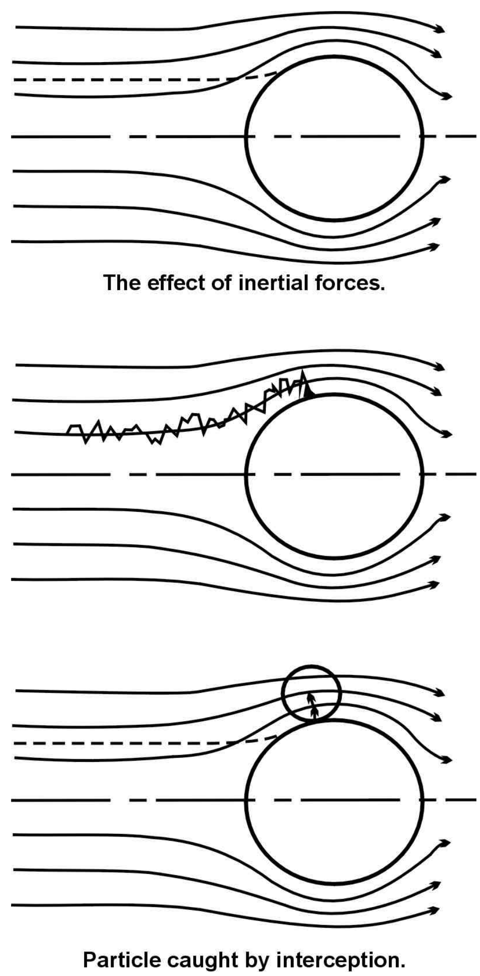

Figure 3.2 – Streamlines around a filter fiber